TRACKING THE P–T PATH OF PRECAMBRIAN ECLOGITE USING PSEUDOSECTION, Ti-IN-QUARTZ AND Zr-IN-RUTILE THERMOBAROMETRY

Lorraine Tual, Charlotte Möller, Pavel Pitra, Martin Whitehouse

Tracking the P–T path of Precambrian eclogite using pseudosection, Ti-in-quartz and Zr-in-rutile thermobarometry.

Lorraine Tual [1], Charlotte Möller [1], Pavel Pitra [2] and Martin Whitehouse [3]

[1] Department of Geology, Sölvegatan 12, SE-223 62 Lund, Sweden, [2] Géosciences Rennes, UMR CNRS 6118, Université Rennes 1, 35042 Rennes, Cedex, France, [2] Swedish Museum of Natural History, Box 50 007, SE-104 05 Stockholm, Sweden

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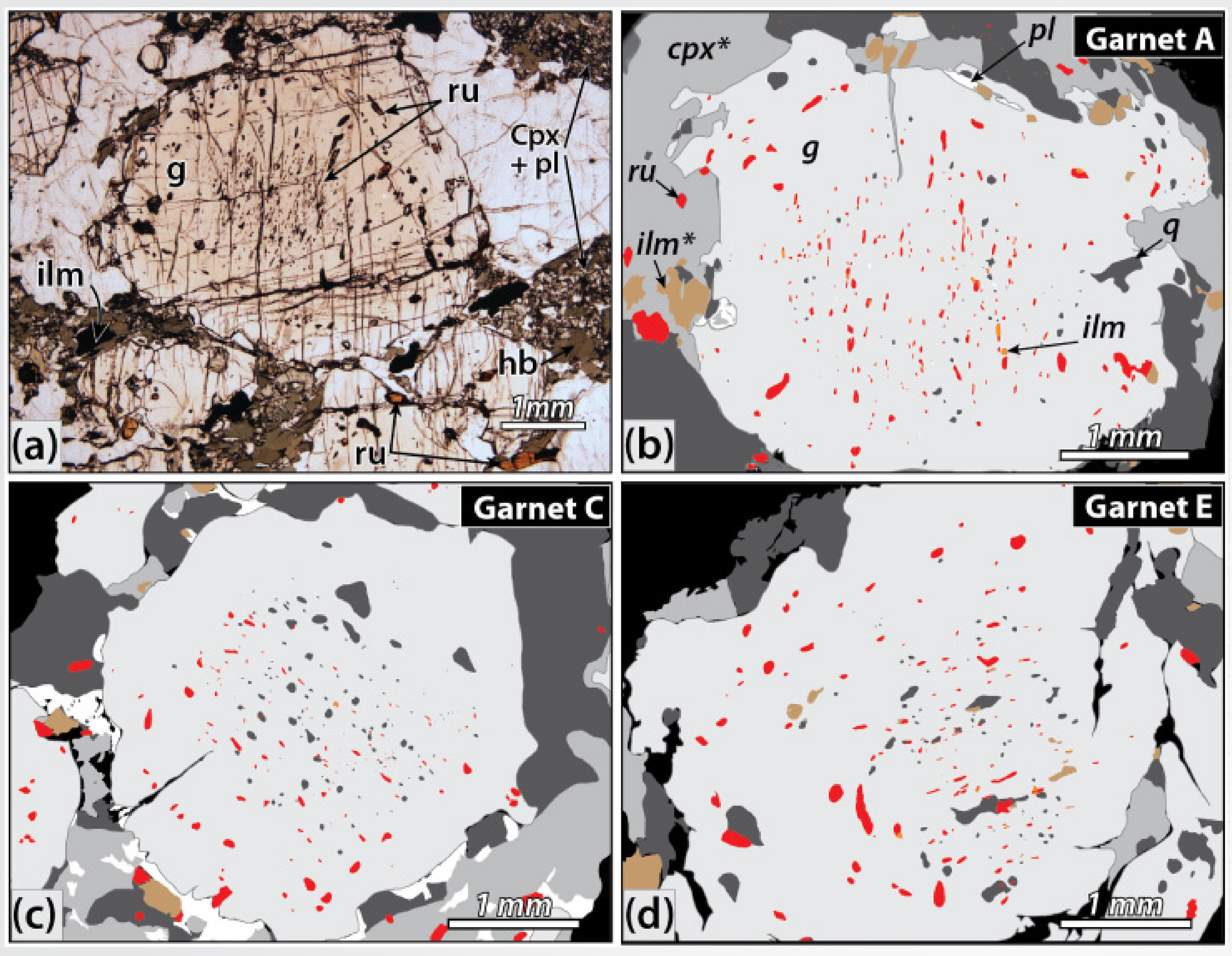
Highlights of the poster

We present the first quantitative P–T path for eclogite from the Sveconorwegian orogen, interpreted from pseudosection modelling (THERMOCALC).

We confirm the steep prograde P–T path, reaching ~900°C using Ti-in-quartz and Zr-in-rutile thermobarometry.

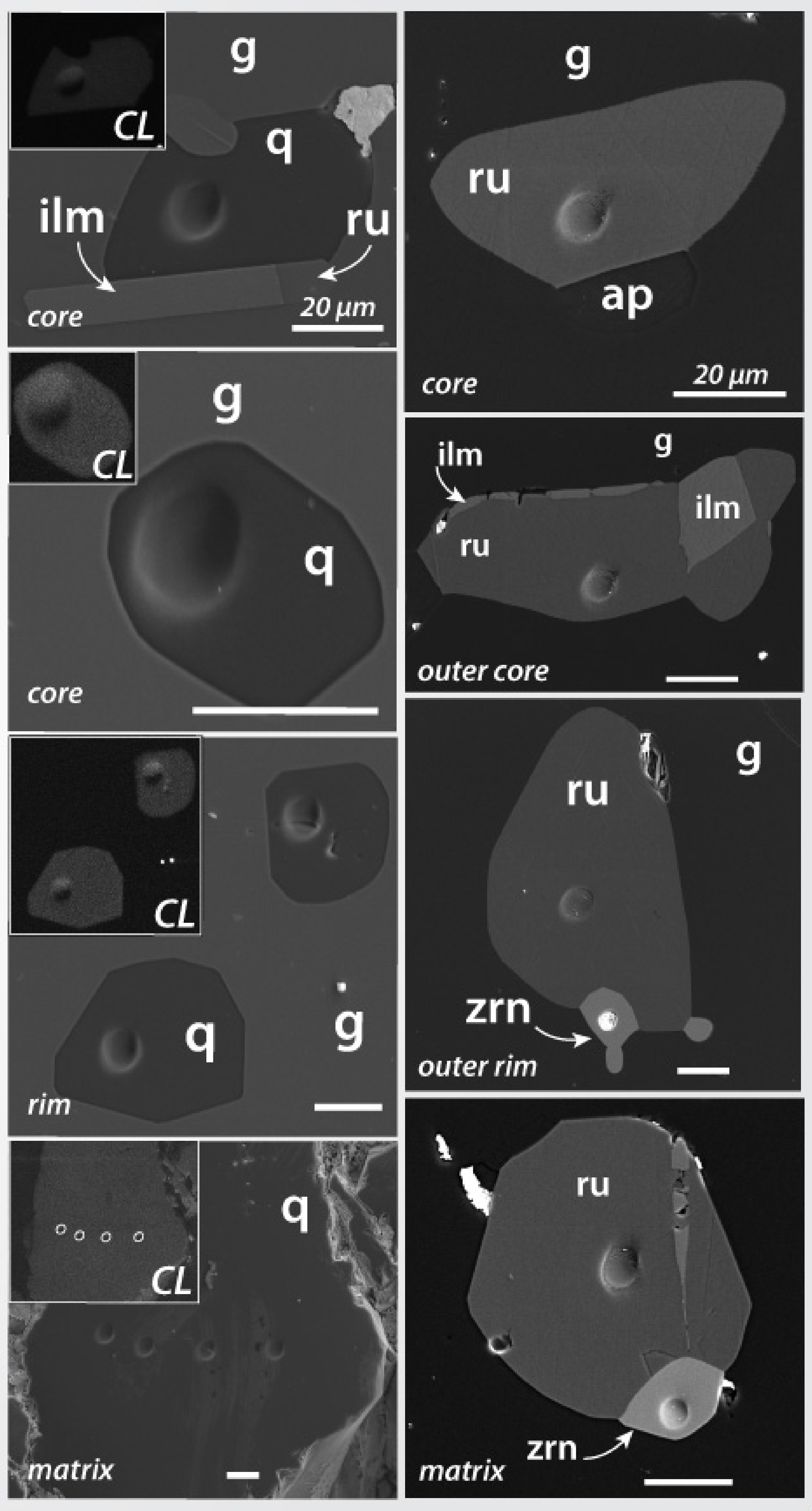
We demonstrate the significance of a major dehydration reaction, which led to recrystallization of large matrix rutile and quartz. This reaction is crucial to understand the rock's crystallization and interpret thermometry results.

Petrography



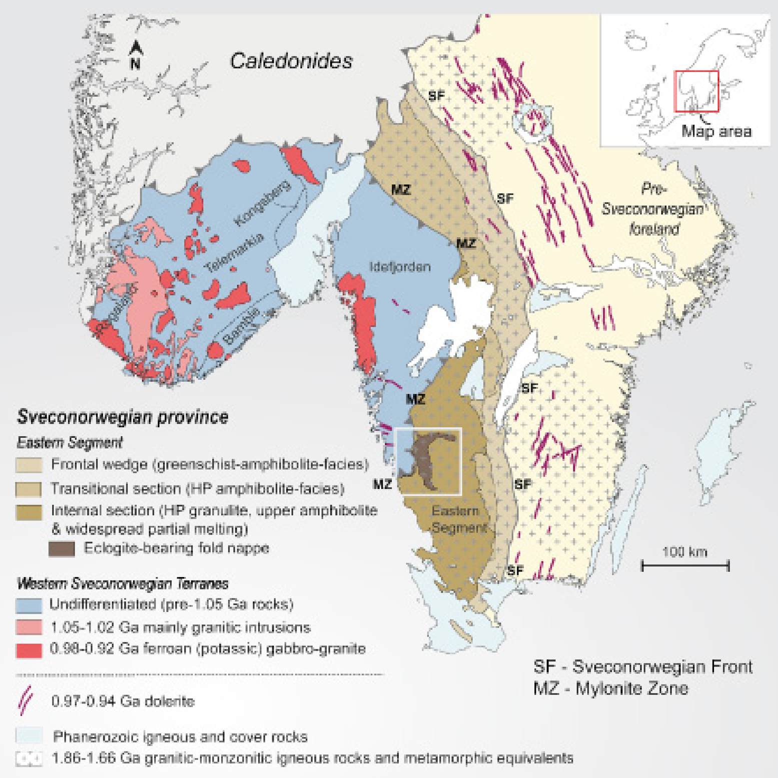
The sample is a Fe-Ti rich eclogite variety. Garnet is 3-5 mm large, constitutes 70% of the sample and has a distinct core-and-rim structure. Inclusions are mostly made up of rutile, quartz, zircon, ± ilmenite. An inclusion-poor zone in the inner rim of garnet separates the core from the outer rim; in the outer rim rutile and quartz grains are 5-10 times larger than in the core, and their orientations follow the garnet rim.

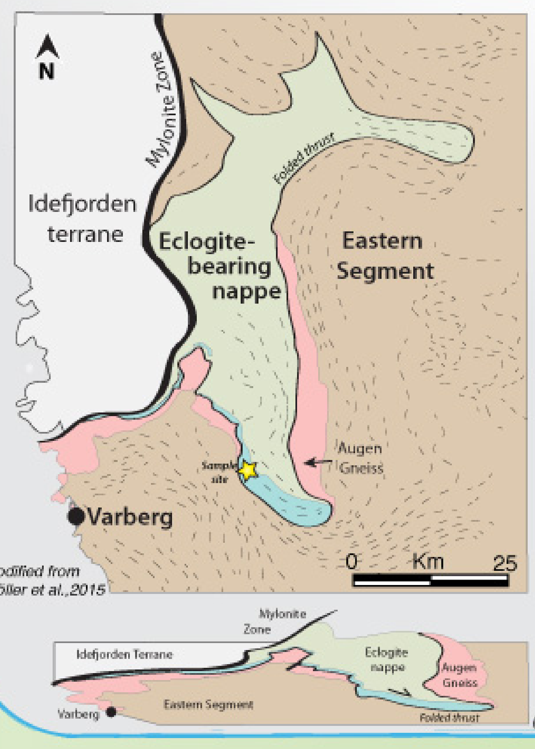
Three garnet grains (A, C, E) were selected for Ti-in-quartz and Zr-in-rutile analysis. Rutile coexists with ilmenite in garnet core, whereas it is partly replaced by ilmenite in the matrix (ilm*). Quartz grains do not show CL-zoning. Zircon is present in all textural settings: in the garnet cores, garnet rims and in the matrix. In-situ SIMS analyses were performed on both rutile and quartz (spot diameter of 10μm).



Sveconorwegian orogen

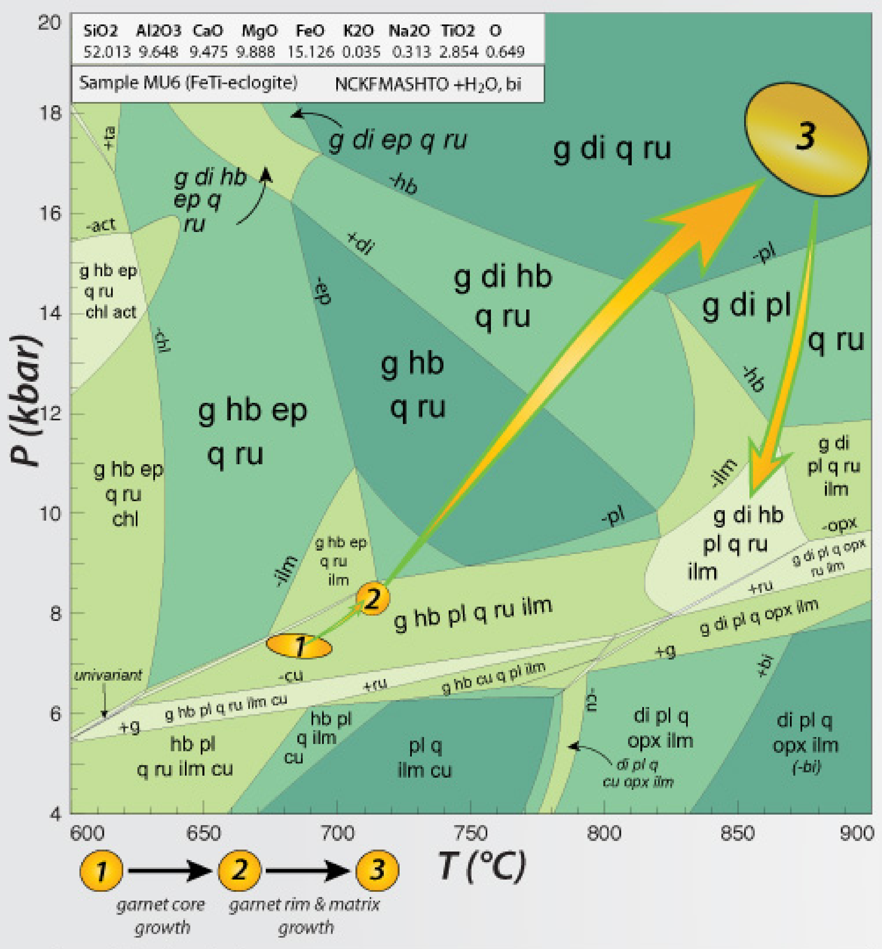
The Sveconorwegian orogen is a 500 km wide belt in SW Scandinavia which underwent accretion to collisional orogeny 1.14-0.92 Ga (*e.g.* Bingen *et al.*, 2008). Today the orogen is eroded and exposes deep sections of the mountain chain. Eclogite is present in the easternmost part of the orogen, the Eastern Segment, which is the lithological continuation of Baltica crust (*e.g.* Möller *et al.*, 2015). The eclogites are bound within a recumbent fold nappe, which lies just underneath the contact with the Idefjorden Terrane (white square to the right; Möller *et al.*, 2015).





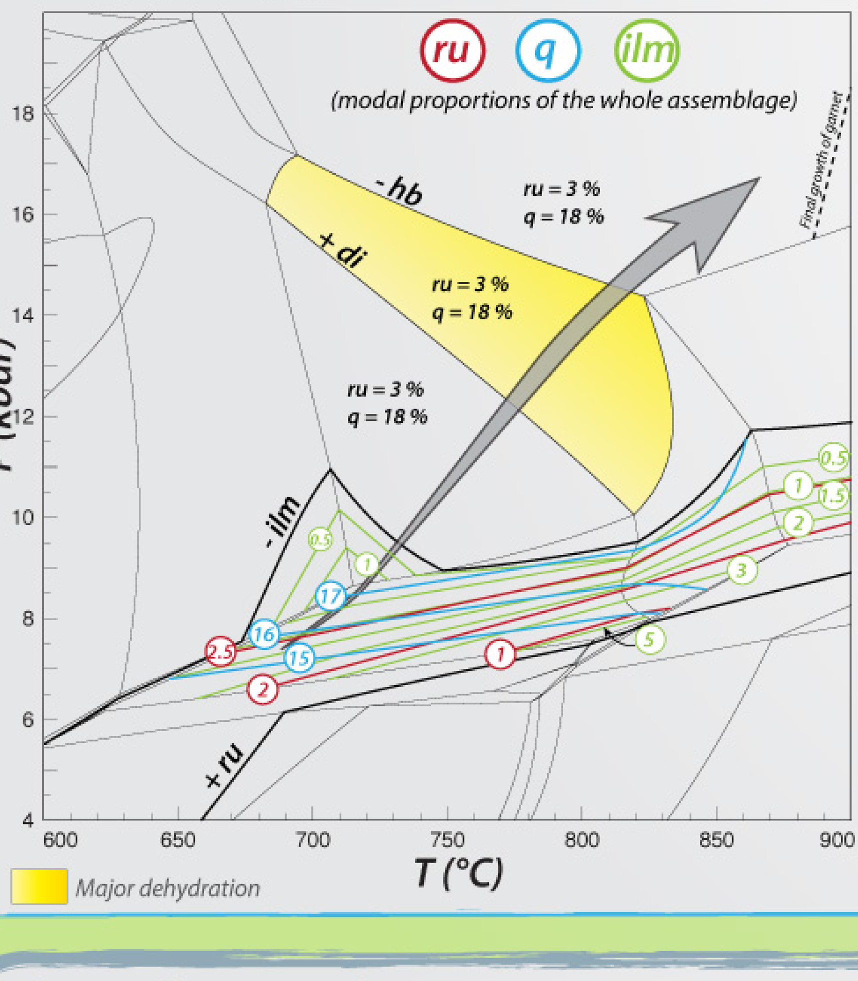
The nappe represents a part of a continental crust that experienced westward tectonic burial at eclogite-facies conditions beneath the western Sveconorwegian terranes, followed by eastward, foreland-directed, tectonic exhumation at granulite facies conditions (Möller, 1998, 1999; Möller *et al.*, 2015; Tual *et al.*, 2015; Tual, 2016). The nappe is made up of rocks similar to the ones enclosing it and do not represent a detached piece of an oceanic slab (e.g. Möller, 1998). Penetrative deformation, polyphasal folding and partial melting are widespread, but particularly pervasive in the eclogite nappe (e.g. Möller *et al.*, 2015; Tual *et al.*, 2015). The timing of eclogite metamorphism and exhumation at 40 km depth is bracketed between 0.99 and 0.97 Ga (U-Pb SIMS ages of zircon; Johansson *et al.*, 2001; Möller *et al.*, 2015).

Pseudosections



The *P–T* path was interpreted from a pseudosection of the same sample, based on mineral assemblages and garnet composition (left; Tual, 2016). The *P–T* path provides pressure estimates for input in thermometry calculations. The pressure values entered in the equations are:

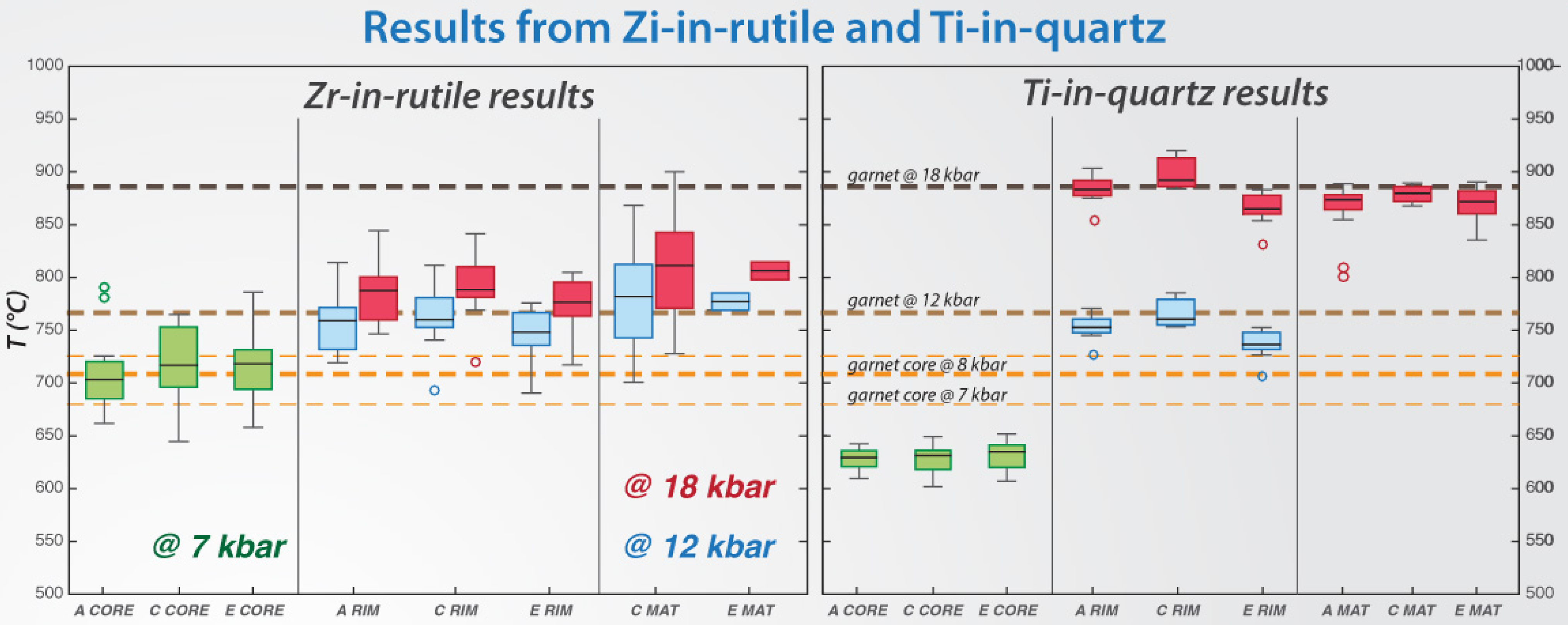
- **7 kbar**, inner garnet core;
- **12 kbar**, inclusion-poor domain in garnet and the uppermost limit for garnet core and lowermost limit for garnet rim
- **18 kbar**, outer garnet rim and matrix.



The modal abundances of rutile and ilmenite show that rutile was produced by continuous breakdown of ilmenite during the early stages of prograde metamorphism, a reaction that ran to completion at ~730 °C.

Rutile grains in the garnet rim and the matrix thus grew larger by recrystallization of previously produced rutile. This recrystallization is interpreted to have been particularly efficient at 775–815 °C, the stage during which hornblende was consumed and clinopyroxene produced, i.e. during dehydration of the rock.

Results from Zi-in-rutile and Ti-in-quartz



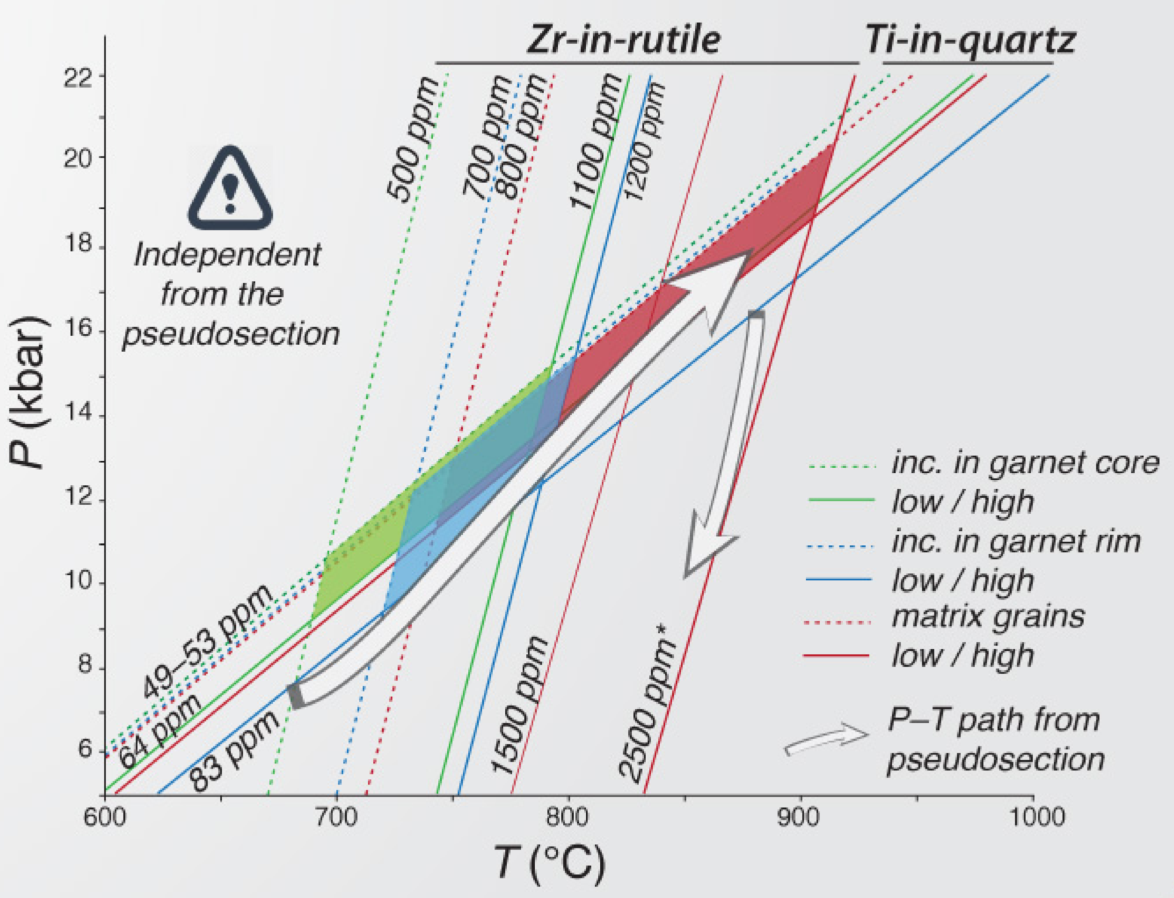
Zr-in-rutile temperatures calculated using the calibration of Tomkins et al. (2007). Good agreement with pseudosection for inclusions in garnet core and inner rim, but not for matrix grains.

Ti-in-quartz temperatures calculated using the calibration of Thomas et al. (2010). Good agreement with pseudosection for grains in garnet rim and matrix, but not for garnet core inclusions.

The Ti-in-quartz and Zr-in-rutile thermometers are both moderately and slightly pressure sensitive, respectively. Combining the Ti in quartz and Zr in rutile contents of all grains allow independent cross-check of the results (independent from pseudosection; right; method after Thomas *et al.*, 2010).

Results are in nearly perfect agreement with the pseudosection.

Apparent low-*T* recorded in quartz inclusions in garnet core may be due to incomplete equilibration during fast garnet growth. Low-*T* recorded by rutile grains included in the garnet rim and in the matrix is likely due to recrystallization and increase of rutile grain size during the main dehydration reaction (cf. left), after which it largely ceased. Alternatively, low-*T* recorded in rutile can be due to kinetic reasons *i.e.* too fast recrystallization of rutile grains leading to Zr-undersaturation).



Ongoing projects

Raman barometry using quartz inclusions in garnet.

The main peaks in the Raman spectra of α-quartz vary with temperature and pressure, a relationship that has been reproduced in experiments (Schmidt & Ziemann, 2000). Because garnet can form robust armour around quartz inclusions, applications of Raman thermobarometry on quartz inclusions in garnet have yielded successful results (e.g., Enami et al., 2007; Ashley et al., 2014). Preliminary application of this technique was undertaken on quartz inclusions in garnet using different sample types: a hand polished slab, a thin section, and an epoxy mount (the same as used for thermometry analysis). A total of 80 spectra from small quartz inclusions (5-20 μm) were collected, but only a few spectra show shifts ~1.5 and up to 2.9 cm^{-1} which corresponds to entrapment pressures of 13–15.5 kbar (calibration Guiraud and Powell, 2006) and 16-18.5 kbar (calibration Zhang, 1998).

In situ SIMS U-Pb dating, REE analysis, and thermometry on zircon

This ongoing project is a SIMS study of zircon in eclogite and includes (1) U-Pb dating of zoned zircon, (2) REE analysis of zircon domains and metamorphic minerals, and (3) Ti-in-zircon thermometry, performed on the same mount presented here. Separated zircon grains were mounted on a second mount; some grains are from the whole rock and others were carefully handpicked from pure separated and hand-crushed garnet fractions. Zircon grains included in garnet will track the prograde history of the rock (or, alternatively, even older events). Presence of prograde zircon in this sample (textural and geochemical evidence) constitute a rare opportunity to yield a high resolution *P–T–t* path by application of the most recent and robust "petrochronologic" tools.

Summary

Although rutile is commonly very robust to record peak metamorphism at high-temperature, we demonstrate that a major dehydration reaction led to recrystallization of most rutile grains before the metamorphic peak. Alternatively, rutile grains grew too fast due to the dehydration reaction for all grains to reach Zr saturation.

Nevertheless, both Ti-in-quartz, Zr-in-rutile and the *P–T* pseudosection show the same (steep) prograde path and firmly constrain the metamorphic evolution of the Sveconorwegian eclogite.

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